

## **General Disclaimer**

### **One or more of the Following Statements may affect this Document**

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

MAR 29 1983

(NASA-CR-170752) CALIBRATION OF THE ACTIVE  
RADIATION DETECTOR FOR SPACEIAE-CBE Annual  
Report (Alabama Univ., Huntsville.) 19 p  
HC A02/MF A01 CSCI 14E

883-24833

Unclas  
G3/35 11761

# **CALIBRATION REPORT: ACTIVE RADIATION DETECTOR**

---



**The University  
Of Alabama  
In Huntsville**

---



Prepared by:  
John Gregory  
Chemistry Department  
The University of Alabama in Huntsville

T. A. Parnell  
ES62/3-5133

**CALIBRATION OF THE ACTIVE RADIATION DETECTOR**  
**FOR SPACELAB-ONE**

**Annual Report on Contract NAS8-31170**

**December 1982**

**Cosmic Ray and Nuclear Instrumentation Laboratory**

**The University of Alabama in Huntsville**

### SUMMARY

The flight models of the Active Radiation Detector (ARD) for the ENV-01 environmental monitor<sup>\*</sup> were calibrated using  $\gamma$ -radiation. Measured sensitivities of the ion chambers were:

ARD S/N 1:  $6.1 \pm 0.3 \mu \text{ rad per count}$

ARD S/N 2:  $10.4 \pm 0.5 \mu \text{ rad per count.}$

Both were linear over the measured range 0.10 to 500 m rad hour<sup>-1</sup>. The particle counters (proportional counters) were set to respond to approximately 85% of minimum ionizing particles of unit charge passing through them. These counters were also calibrated in the  $\gamma$ -field.

<sup>\*</sup>This instrument is being developed for the VFI program by the Space Science Laboratory of NASA, MSFC for flight on Space lab 1. A full description of the instrument is not given here.

### ION CHAMBER DOSIMETERS

The tissue-equivalent ion chamber dosimeters (IC's) are designed\* to make differential measurement of absorbed dose in a mixed radiation field typical of Spacelab orbits. Each dosimeter consists of a gas-filled ion chamber, electrometer sensor, and pulse generator. When each preset unit of radiation (measured in tissue-rads) is accumulated, a pulse is sent to advance an internal register and reset the electrometer integrator. Preset dose units are in the range of 5 to 10  $\mu$  rads per pulse and expected count rates in orbit vary from a low value of a few counts per hour to a few counts per second in the South Atlantic anomaly.

The calibration procedure is designed to measure the sensitivity of the instrument in  $\mu$  rads per count, and to check the linearity of the system over the expected dose rate range of up to several hundred  $\mu$  rads per hour.

A view of the ion chamber assembly is shown in Figure 1.

\* TEIC I/E1, Digital Data Dosimetry, Tulsa, Oklahoma.

# CALIBRATION

## Dose Calculation

$$\begin{aligned} \text{Energy absorbed per gm} &= \frac{\mu}{\rho} \cdot F \quad \text{ergs g}^{-1} \\ &= \frac{\mu}{\rho} \cdot \frac{F}{100} \quad \text{rads} \end{aligned} \quad (1)$$

where  $\mu/\rho$  is the energy transfer coefficient (for tables, see Hubbell and Berger, 1965), and

$F$ , the energy flux in  $\text{ergs cm}^{-2}$ ,

$$= \frac{3.7 \times 10^{10} \times \text{source strength in Ci} \times E_{\gamma} \times 1.6 \times 10^{-12} \text{ ergs cm}^{-2}}{4\pi r^2} \quad (2)$$

where  $E_{\gamma}$  is the proton energy in eV

and  $r$  is the source-absorber separation in cm.

Some measured and calculated dose rates of interest are shown in Table 1.

T A B L E 1

Some dose rates of interest:

Typical sea level background in US:	$\sim 10 \mu \text{ rad hour}^{-1}$
10 $\mu$ Ci Cs-137 @ 30 cm:	37 $\mu \text{ rad hour}^{-1}$
10 $\mu$ Ci Cs-137 @ 5 cm:	1.3 m rad hour <sup>-1</sup>
100 m Ci Cs-137 @ 50 cm:	130 m rad hour <sup>-1</sup>
South Atlantic anomaly peak:	$\sim 100 \text{ m rad hour}^{-1}$

### Experimental Arrangement

The setup used is shown in Figure 2. Both source and detector are at a fixed distance ( $\sim 1$  m) from the floor. The source position was unchanged but the detector and shield were on a movable trolley. The source used was a nominal 100 m Ci of Cs-137 (New England Nuclear NER 401 H, serial number CS-315) of actual activity  $93.8 \pm 5$  m Ci on August 8, 1975. At the time of this calibration, its activity was 79.2 m Ci.

The ARD was placed in the  $\gamma$ -field so that the IC and both PC's were equidistant,  $d$  meters, from the source. The number of counts per unit time for each detector was recorded. For the PC's the mean of 17 measurements of counts per second was taken in each case. For the ion chamber, the counting interval was varied depending on the count rate so that the uncertainty in counting was less than 3%. At count rate  $> 50$  per 100 s a counting period of 100 s is adequate. At lower count rates longer interval were used, and at very low rates of a few per 100 s or less, the measurement was made of the intervals between actual counts. This is conveniently done with the GSE since the count register of the ARD is read out and displayed every second by the GSE.

These results for the ion chambers are shown in Figure 3 and 4 for ARDS's 1 and 2 respectively. Plots of PC count rate versus dose rate are shown in Figures 5, 6 and 7.

From this data and equation (2) the sensitivities of the ICs were determined to be:

ARD No. 1 -----  $6.1 \pm 0.3 \mu \text{ rads (ct)}^{-1}$

ARD No. 2 -----  $10.4 \pm 0.5 \mu \text{ rads (ct)}^{-1}$

The IC's are seen to be linear over the range  $300 \mu \text{ rads hour}^{-1}$  to  $100 \text{ m rads hour}^{-1}$  are probably linear up to an order of magnitude higher in dose rate.

### PROPORTIONAL COUNTER RATE METERS (PC'S)

These counters are xenon-filled stainless steel cylinders with aluminum liners (Reuter-Stokes #RS-P3-0803-287). Shown in Figure 8, they are 4 inch long and 1 inch in diameter. There are two PC's in each ARD, one being covered with a copper sleeve 1.27 mm thick for partial discrimination between protons and soft electrons.

Any charged particle intersecting a PC or any photon interacting within a PC will advance the ratemeter for that counter, provided sufficient energy is deposited in the counter to exceed the preset threshold discriminator. For a given radiation field the count rate varies with the system gain and noise and with the discriminator level. This level was set above system noise but low enough to be exceeded by most minimum ionizing singly-charged particles.

#### Energy Loss Calculation and Discriminator Level Justification

Mean ionization loss for relativistic  $z = 1$  particle in Xe =  $7.5 \text{ keV cm}^{-1}$ .

Mean ionization loss across a diameter of the PC =  $19.5 \text{ keV}$ .

With discriminators set at  $8.9 \text{ keV}$ ,  $> 90\%$  of all particle trajectories intersecting the PC will exceed this level. Since some particles deposit less than the mean, an overall efficiency of  $85\%$  is estimated for relativistic particles. Efficiency is greater for slower particles of sufficient energy.

#### Consistency of PC Background Count rate with Other Measurements

An experimental measurement of the fast muon flux at Huntsville using the MSFC-UAH cosmic ray instrument gave approximately  $0.012 \text{ (cm}^2 \text{ sr)}^{-1}$ . For the effective area of these PC's of  $18 \text{ cm}^2$  we should expect a fast muon rate of about  $0.4 \text{ s}^{-1}$ . Actual measured background count rates with the ARD PC's were in the range  $0.6$  to  $1.5 \text{ s}^{-1}$ . Since this includes all background radiation, the AC measurement is in agreement with prediction.

The energy deposit calibration of the PCs was made using low energy photon sources of  $5.9 \text{ keV}$  (Fe-55) and  $14.4 \text{ keV}$  (Co-57). The excellent resolution and noise figure of these counters is shown in Figure 9.

Count rates of the PC's in a calibrated  $\gamma$ -field were recorded during the calibration of the ion chambers by the shadow-shield method described below. Plots of count rate versus dose as measured by the ion chambers are shown in Figures 5, 6 and 7.

The proportional counters are not quite linear with dose rate as shown in the figures. In the event of IC failure, however, they will give a reasonable estimate of dose rate. The presence on PC No. 2 of the  $1.27 \text{ mm}$  thick copper shield did not affect the counting rate greatly compared to PC



No. 1 for 0.66 MeV  $\gamma$ -rays. It will, however, affect the count rate for low energy electrons.

#### Transfer Calibration and Check Source

During the period between calibration and flight, (approximately one year), checks must be made of the ion chamber (a) to see if it is operating and (b) to check the constancy of the sensitivity ( $\mu$  rads  $\text{ct}^{-1}$ ).

This is effected with a small source placed on a marked spot on the aluminum case of the ARD. The source strength is 10  $\mu$  Ci and the effective separation of source and detector is 5 cm. The dose rate is 1.3 m rad  $\text{hour}^{-1}$ , approximately two orders of magnitude above laboratory background and two orders below orbital maximum rate (see Table 1). Baseline data using the transfer calibration source and background measurements are given for ARD's No. 1 and 2 in Tables 2 and 3 respectively.

ORIGINAL PAGE 18  
OF POOR QUALITY

TABLE 2

## TRANSFER CALIBRATION/CHECK SOURCE MEASUREMENTS

ARD No. 1

Source on IC Spot

<u>DATE</u> (1982-1983)	<u>PC 1</u> counts/sec (mean of 17 measurements)	<u>PC 2</u>	<u>IC</u> time for 1 count (sec)
December 29	7.7	19.4	16.5
29	8.1	20.2	16.0
30	9.2	19.4	16.2
30	9.4	17.6	15.8
January 2	8.9	17.0	16.1
2	7.6	21.0	16.2
2	7.8	17.9	15.9
2	8.5	18.7	16.1
5 (post shake)	9.0	21.2	14.7
5	8.8	19.6	14.7
5	10.2	20.0	14.9

Source on PC Spot

December 29	108	107	----
30	105	109	----

Room Background

December 29	1.53	1.12	1100
29	1.59	1.06	
30	1.06	0.94	

TABLE 3  
TRANSFER CALIBRATION/CHECK SOURCE MEASUREMENTS  
ARD No. 2

Source on IC Spot

<u>DATE</u> (1982-1983)	<u>PC 1</u> counts/sec (mean of 17 measurements)	<u>PC 2</u>	<u>IC</u> time for 1 count (sec)
December 29	7.7	17.7	----
29	8.1	17.3	----
30	8.8	18.5	----
30	8.5	18.7	----
30	9.5	17.5	----
January 2	8.0	16.6	----
2	8.1	17.1	----
2	8.1	18.3	----
2	7.3	19.4	----
8 (reconstituted post shake)	9.5	19.4	26.5
	10.2	17.6	28.2
	8.6	18.8	28.3
	9.7	19.8	28.2

Source on PC Spot

December 29	109	104	----
	111	100	----
January 8	96	114	----

Background

December 29 (in rad. fac.)	0.7	0.6	1500
	0.9	0.4	
January 8 (in SSL)	2.2	1.2	

ORIGINAL PAGE IS  
OF POOR QUALITY

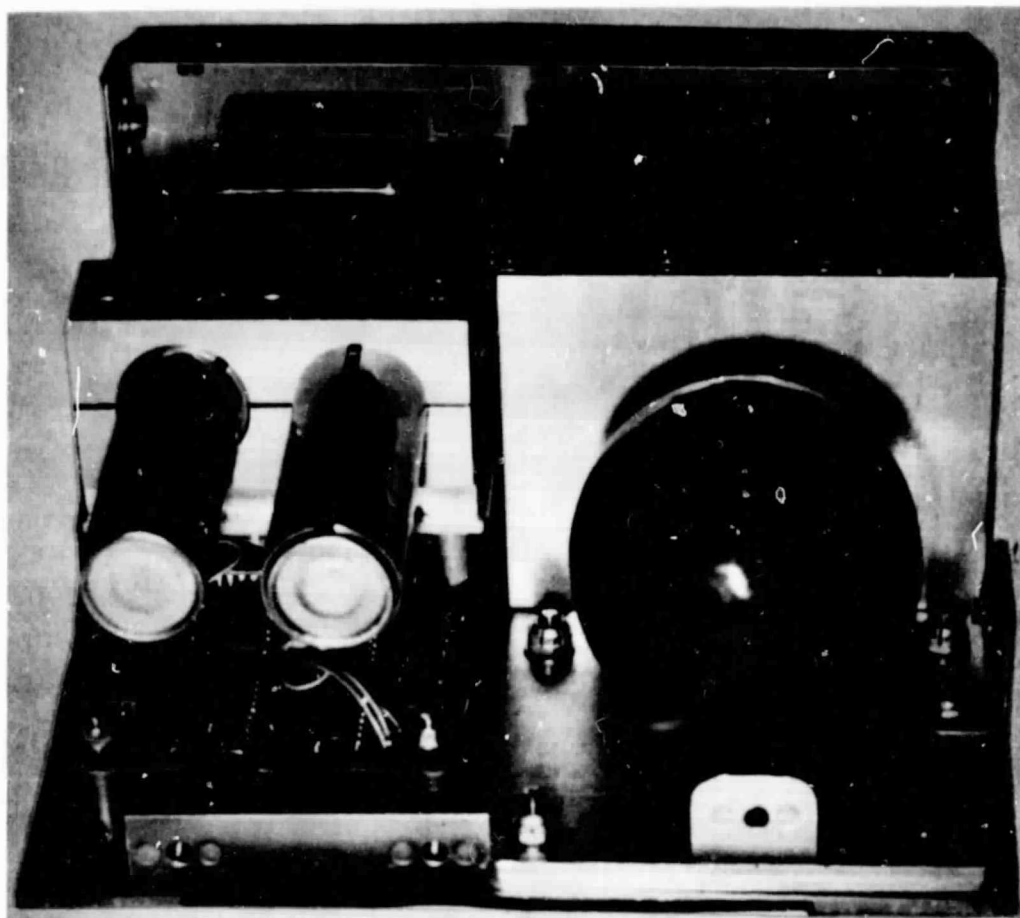


FIGURE 1. ACTIVE RADIATION DETECTOR  
(PROTECTIVE COVER REMOVED)

ORIGINAL PAGE 19  
OF POOR QUALITY

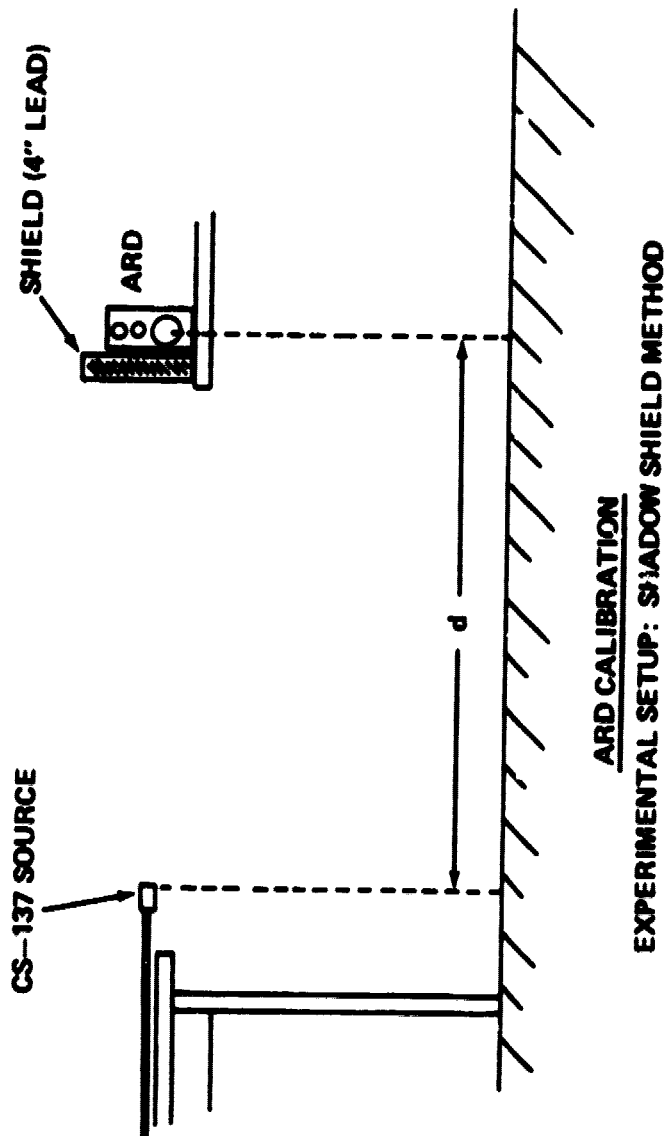
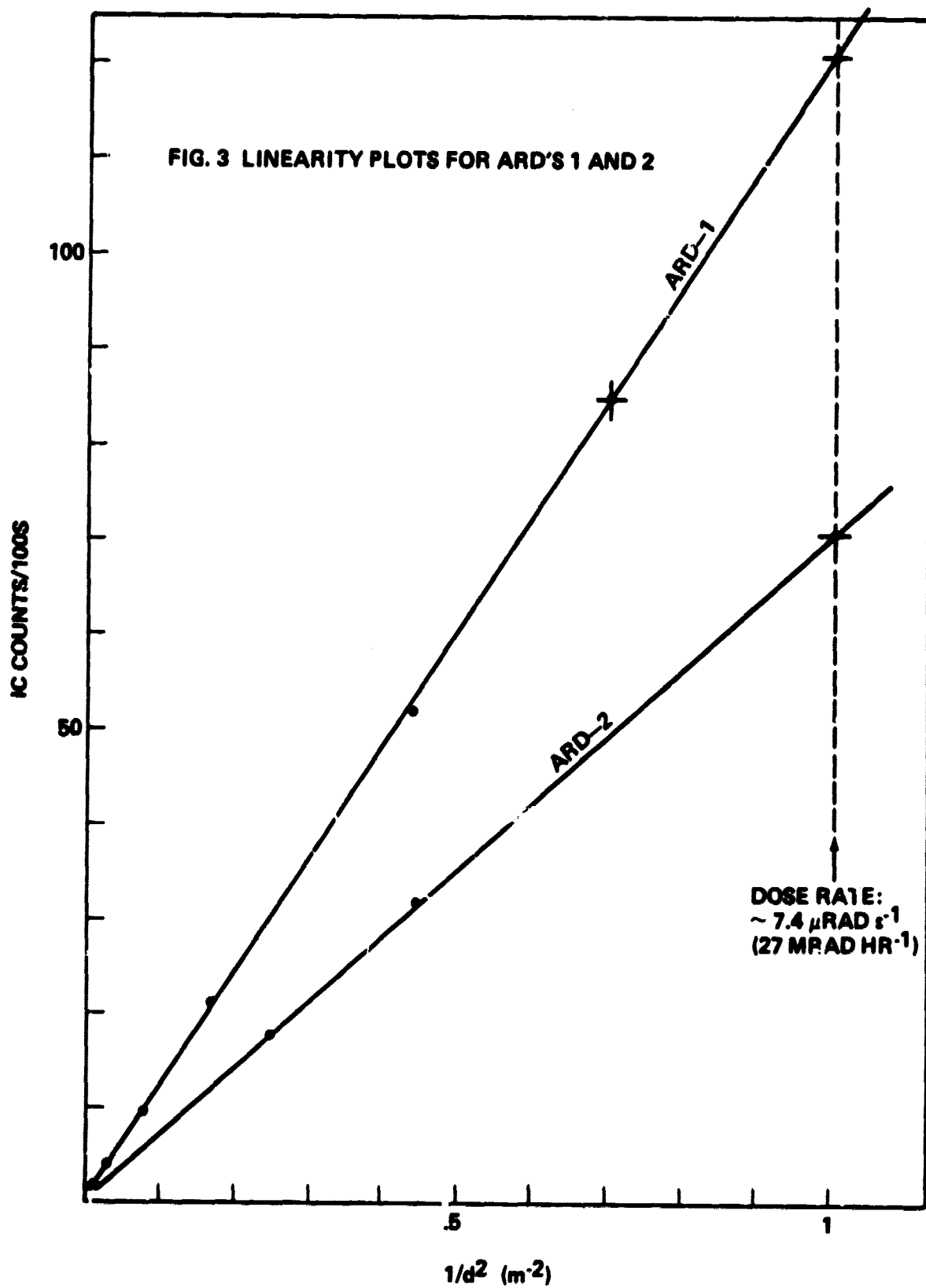
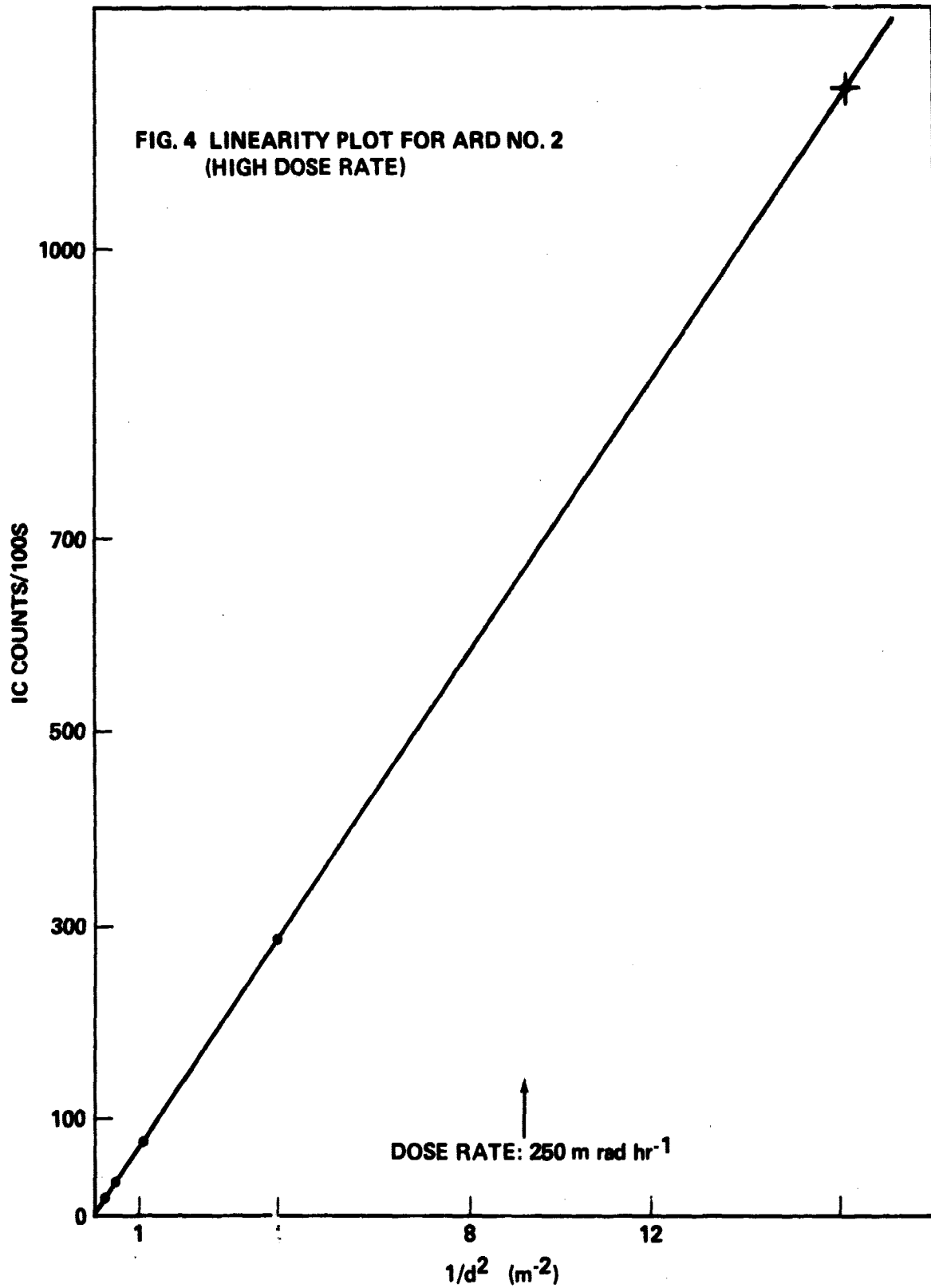


FIGURE 2.

ORIGINAL PAGE IS  
OF POOR QUALITY



ORIGINAL PAGE IS  
OF POOR QUALITY

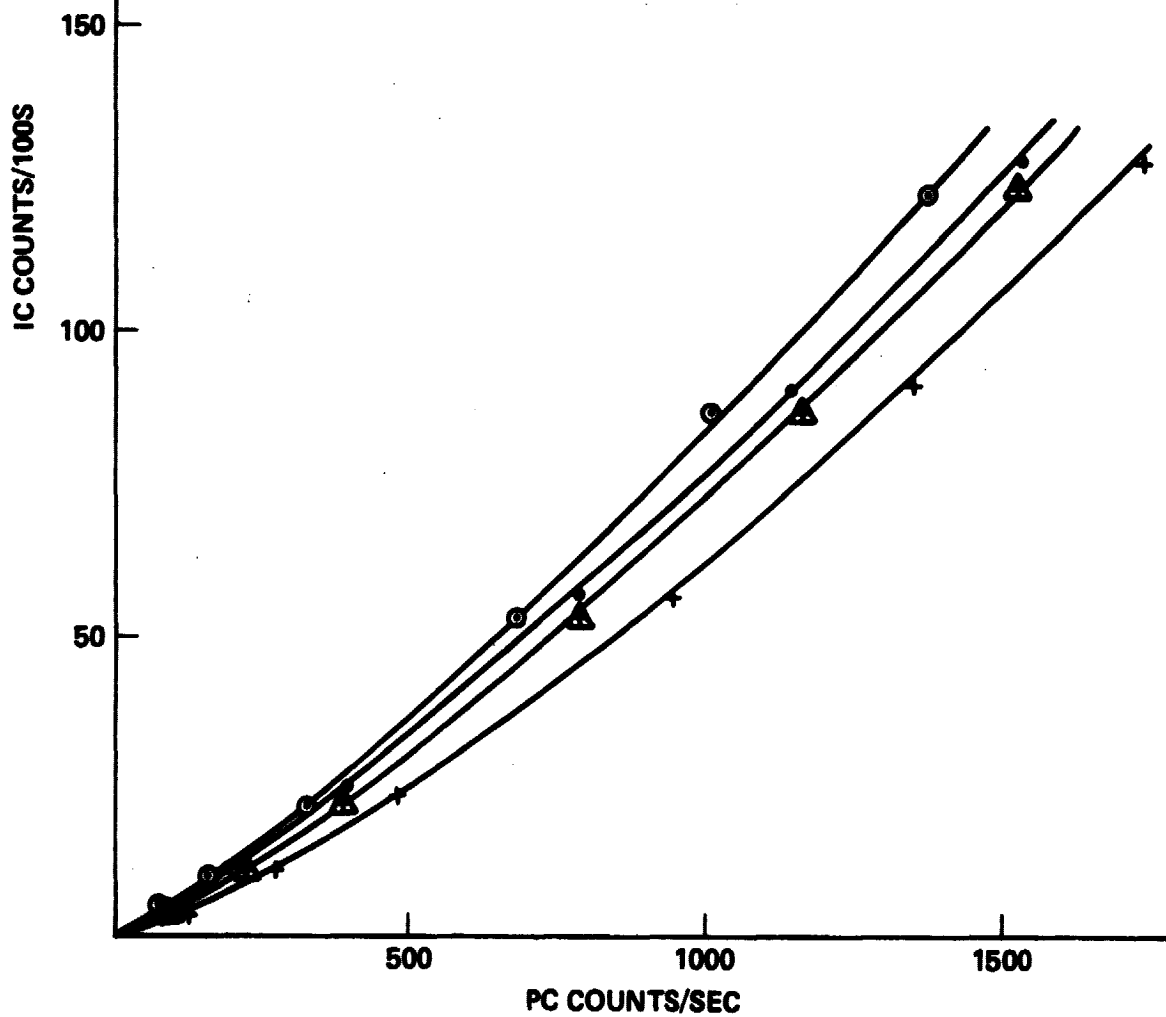


ORIGINAL PAGE IS  
OF POOR QUALITY

FIG. 5 ARD NO. 1

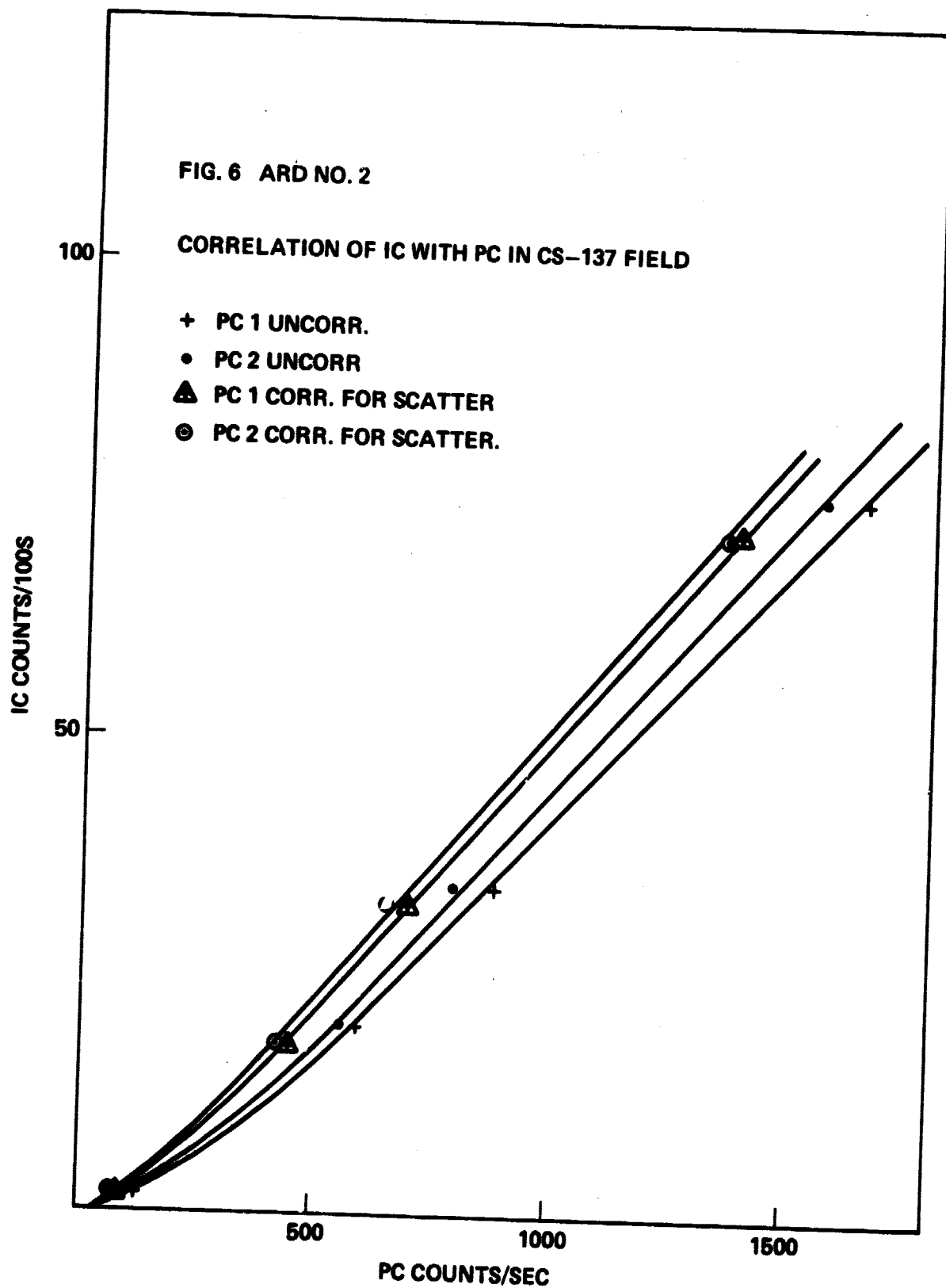
CORRELATION OF IC WITH PC IN CS-137 FIELD

- + PC 1 UNCORR.
- PC 2 UNCORR.
- ▲ PC 1 CORR FOR SCATTER
- PC 2 CORR FOR SCATTER

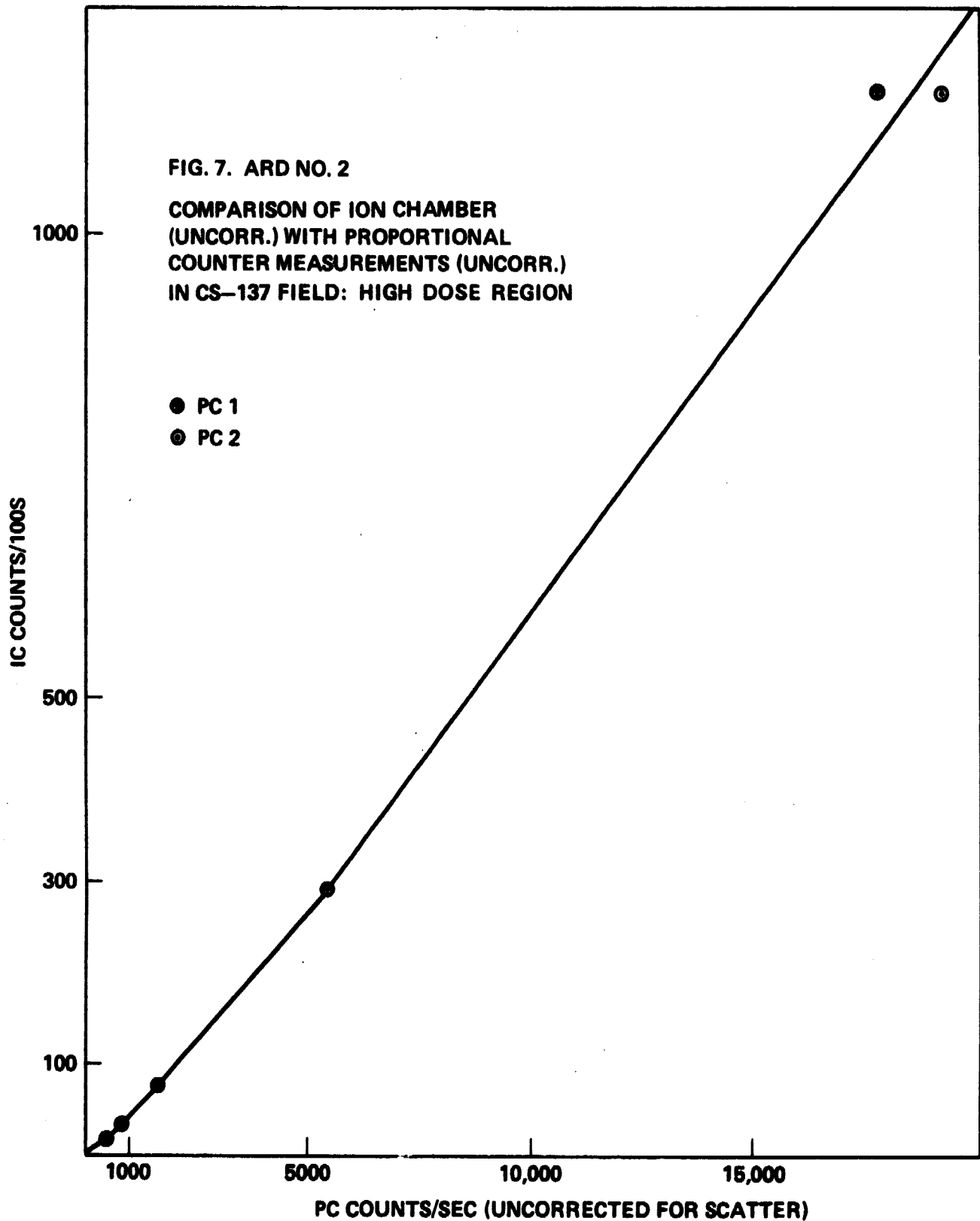




ORIGINAL PAGE IS  
OF POOR QUALITY



ORIGINAL PAGE 19  
OF POOR QUALITY



ORIGINAL PAGE 15  
OF POOR QUALITY

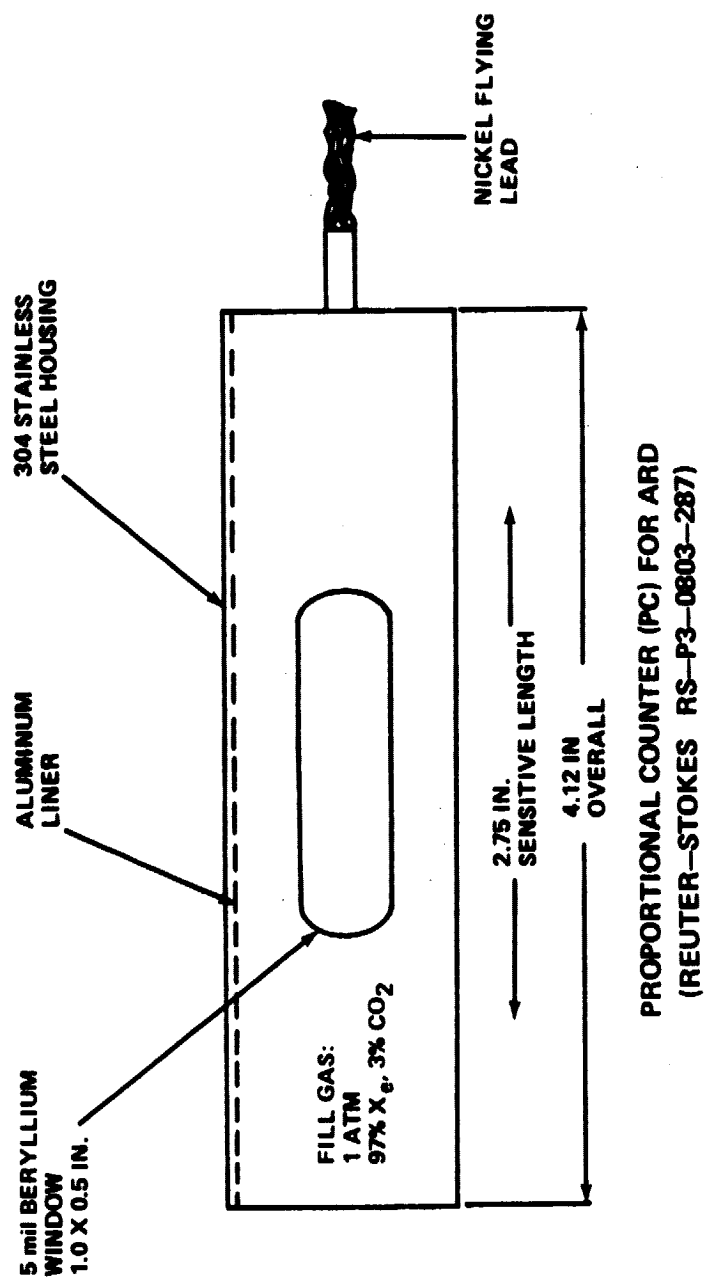


FIGURE 8.

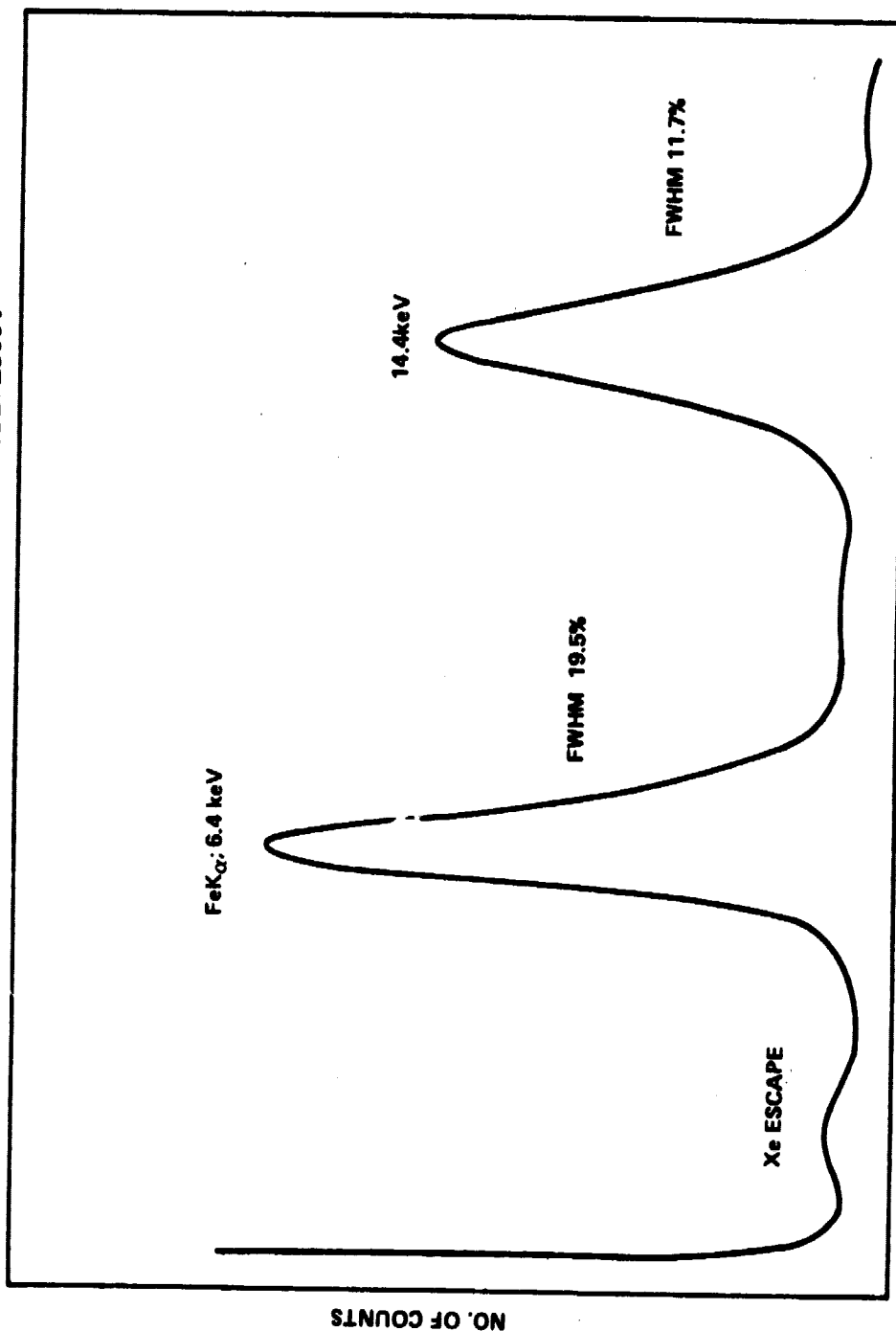
ARD PROPORTIONAL COUNTER ENERGY RESPONSE:

$\text{Co}^{57}$  RADIATION

REUTER STOKES RSP 3-0803-287

SERIAL NO.: W-523

VOLTAGE: 2300V



CHANNEL NO. (ENERGY)

FIGURE 9.